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ANOTHER SOURCE OF J/ψ PARTICLES IN HADRONIC COLLISIONS

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Abstract

We point out the existence of a hadronic decay mode of the $\chi(3550)$ to J/ψ which has hitherto not been considered in theoretical models seeking to explain the mechanism of hadronic J/ψ production.

I. Introduction

At present, there exist two distinct models that purport to explain hadronic J/ψ production within the frame work of the quark-parton picture. The first (the non-singlet model)[1] envisages the formation of a $c\bar{c}$ pair by the fusion of two colored gluons (Fig. 1(a)). The $c\bar{c}$ pair is not in a color singlet state and emits a soft gluon after its formation thereby ending up in a color singlet J/ψ bound state. The second, (the singlet model Fig. 1(b))[2] first forms an intermediate color singlet state by the fusion of two gluons. The χ then decays electromagnetically into the J/ψ. The non-singlet model can predict the energy behaviour of the J/ψ cross section as well as its x dependence by suitable choice of the gluon structure functions. The singlet model, on the other hand, insists on a P wave intermediate state being formed first and the J/ψ being formed subsequently by the emission of a photon. Current measurements of the fraction of J/ψ particles produced from χs by photon emission average around 30% in 185 GeV/c π^-p interactions.[3] The tendency is then to say that the remaining J/ψ s are produced via the non-singlet mechanism. The purpose of this note is to demonstrate that this is not necessarily so, by pointing out the existence of a hadronic decay mode of the $\chi(3550)$ which has hitherto been ignored in all theoretical calculations.

II. The new decay mode

When one asks the question, are there any hadronic decays of the χ that give rise to J/ψ production, the following line of argument results.

a) The decay mode $\chi \rightarrow J/\psi + \pi^{0}$ is forbidden by C parity.

b) Similarly $\chi \rightarrow J/\psi + n(\pi^{0})$ is forbidden by C parity. for any n.

c) $\chi \rightarrow J/\psi + \pi^{+}\pi^{-}$ is forbidden by G parity.

d) $\chi \rightarrow J/\psi + \pi^{+}\pi^{-}\pi^{0}$ is allowed by all the discrete symmetries of the strong interaction.

e) $\chi \rightarrow J/\psi$ + k pions where $k>3$ is forbidden by phase space.

Hence only d) is allowed. When one adds up the masses of the final state particles, one gets 3.511 GeV with an error of 2 MeV resulting from the uncertainty in the mass of the J/ψ. This implies that the decay mode d) is forbidden for the 0^{++} $\chi(3415)$ and most likely forbidden for the 1^{++} (3508± 4 MeV). However the 2^{++} (3554 ± 5 MeV) has ample phase space (43 ± 5 MeV) to decay down to the J/ψ by this mode as well as electromagnetically.

III. Dates and Branching Ratios

The measured branching ratios of the 2^{++} add up[4] to 22 ±3%. Let us take the extreme case that the remaining 78% of the 2^{++} branching fraction is due to the decay mode d). Then given the fact that 12 ±3.7% of J/ψ is due[5] the electromagnetic decay of the 2^{++} in 185 GeV/c $\pi^- p$ interactions, the hadronic decay mode d) can account for 61± 19% of the J/ψ production. This together with the observed ratio of 19 ± 4% from[5] the 1^{++} will explain 90% of the J/ψ production as being due to χ decay. This is the maximal case and one would not expect the branching ratio of the 2^{++} into the decay mode d) to be as high as 80%. Let us also note that in the charmonium system, hadronic decay modes, despite having little phase space, still compete effectively with electromagnetic modes.

An example is the case

$$\psi'(3685) \rightarrow J/\psi + \eta \quad (\Delta m=39.8 \text{ MeV})$$

which competes quite effectively (Branching ratio 4.2%) with the electromagnetic decay $\psi' \rightarrow \chi\gamma$ (7%). Thus the decay mode $\chi(2^{++}) \rightarrow J/\psi + \pi^+\pi^-\pi^0$ could happen a significant fraction of the time. Clearly an experimental measurement of this branching ratio would be most welcome.

Finally let us note that the new decay mode provides a clear and effective method of separating the 1^{++} and 2^{++} χs in hadronic collisions, in experiments which do not have the resolution to do it otherwise. When one computes the effective mass of the γ ray from the π^0 and the J/ψ, this results in a low mass peak at 3.17 GeV with a full width at half maximum of 50 MeV.

In order to observe such a peak in hadronic collisions, measurement of photons down to a lab energy of 1 GeV/c is necessary, given primary beam energies of 150-200 GeV/c. Observation of such a peak would be confirmation of the decay mode under discussion and its magnitude will give the amount of 2^{++} production, once the branching ratio is known.

References

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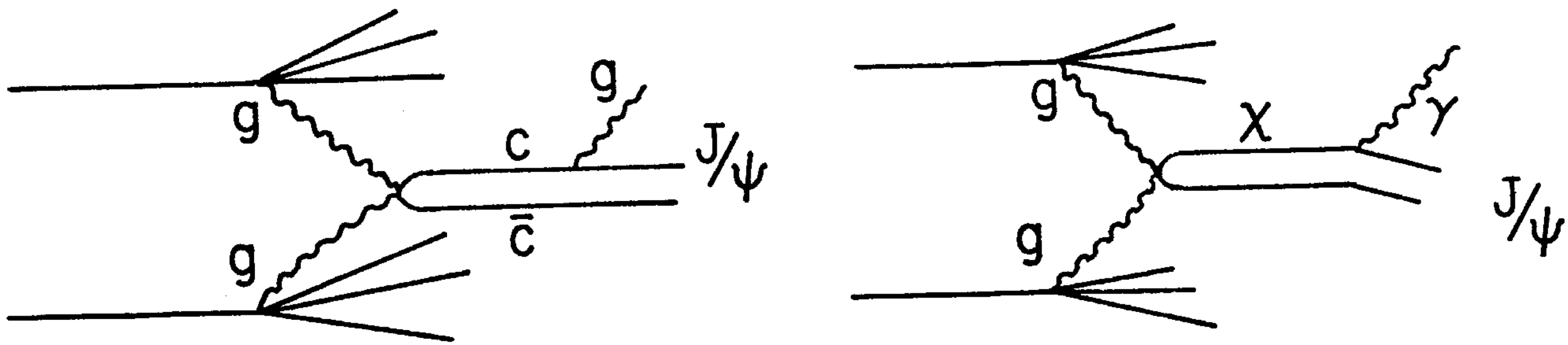
Figure Captions

Fig. 1 a) The non-singlet model. Gluons from the beam and target fuse to form a colored $c\bar{c}$ state which ends up in the J/ψ state by the emission of a soft gluon.

b) The singlet model. Gluons from the beam and target fuse to form an intermediate uncolored P wave state which decays electromagnetically to form the J/ψ.

There are also contributions in either model by light quark fusion, which is not indicated here explicitly.



(a) (b)

Figure 1